Advantages of super-light structures

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Published in:
Proceedings of Nordic Technology Teacher Meeting 2009

Publication date:
2009

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Paper presented at the meeting of Nordic teachers of technology for architectural educations
at DTU, Kgs. Lyngby 15-16 June 2009
version Oktober 2009

Super-light structures

Design the future

www.super-light.dk

Pedestrian bridge in super-light concrete with pearl-chains.
(Student project Iwona Budny, Robert Cybulski, Agnieszka Kotas, Jan Winkler)

0. Super-light structures with Pearl-chain reinforcement

Super-light structures with pearl-chain reinforcement is a new revolutionary technology that opens possibilities of building load-bearing structures much cheaper and with several other advantages compared to traditional constructions of concrete and steel.

Some benefits are:

1 Material savings of 50 %.

2 Energy and CO2 savings of 50 %.

3 Architectural expressions never seen before.

4 Half price or less.

5 No Scaffolding, cheaper moulds, and faster production.

6 Improved durability.

7 Extreme thermal insulation.

8 Better indoor-climate.

9 User friendly operation and maintenance.

10 Increased safety for fire, earthquake, and explosions.

This moves the limits for resource economic buildings.

Roman cupola in light aggregate concrete 100 AC Villa Adriana.
Photo K. Hertz

The new technology consists of a new constellation of well-known materials and parts. All construction methods needed have been widely used for at least 30 years, and apart from high-strength concrete, they have been applied for more than 100 years[1-3].
Avoiding high-strength concrete means that problems with explosive spalling are avoided (Hertz[4-7]) and the structures can be designed according to present codes as for example Eurocodes and fire protected by common principles[8-16].
Only the overall engineering perception of the structure is new. However, this does not deviate more from traditional building technology than many other unusual structures, which are built every day. To be sure, full-scale tests have been made to verify, that nothing has been overlooked.

This means that we have

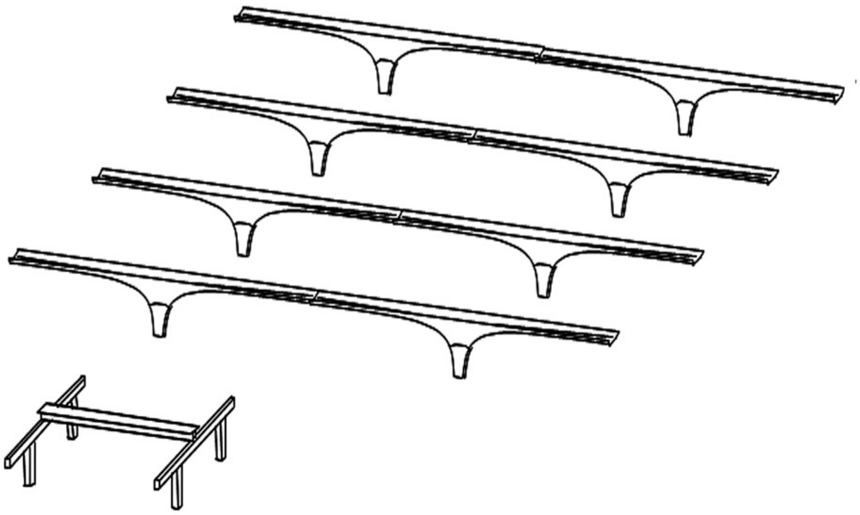
√ *Proof of concept* and
√ *Proof of technology* and

No further development or investments are required before application.

Applications are many:
Buildings, Halls, Shopping centers, Towers, Facades, Roofs, Shells, Bridges, Stadiums, Off-shore structures, Tunnels, Floating foundations, and even Ships are among the many possibilities.
The benefits mentioned above make it very possible that these structures soon will be implemented in practice, so that we will have a

√ *Proof of market*.

The wide range of applications implies that the consequences of this new system are extensive. A research and development centre is being established at DTU Byg in cooperation with Grontmij-Carl Bro consulting engineers Ltd.



Hall with 60 m super-light beams compared with 30 m TT beam technology
Design K. Hertz

0.1 Super-light structures

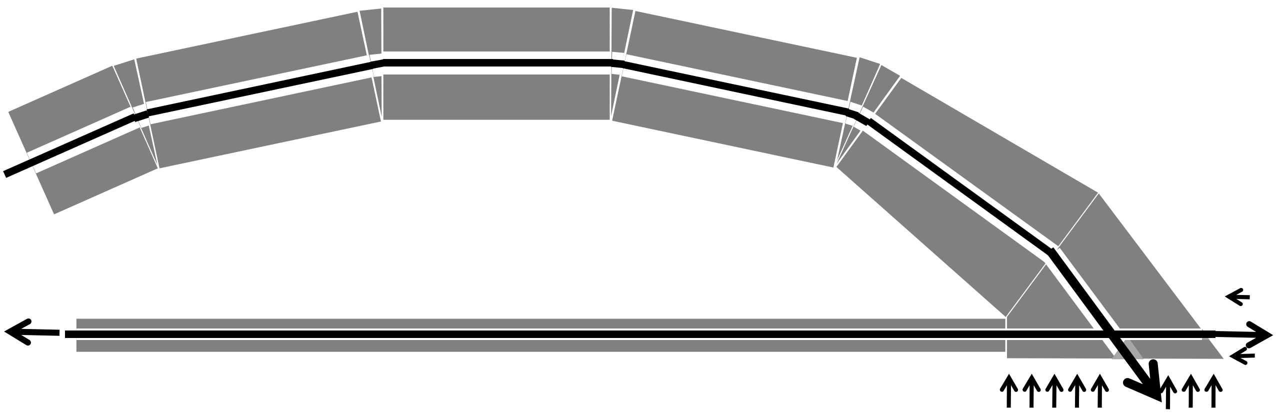
Steel structures are considered to be light compared to concrete structures. The new structures are often light compared to steel structures, and therefore they are called "super-light".

The basic idea of super-light structures is to build a skeleton of a strong material interacting with a stabilizing layer of a light material.

The strong material can for example be made of concrete, brick, or high-strength concrete and the light material can for example be light-weight concrete. However, the basic principle can be applied for any strong and light material.

The light material is usually much cheaper than the strong. It fills out the shape of the structure and applies the load on the skeleton, which is often curved to be optimized. It protects the strong material of the skeleton from impacts and fire, and it prevents it from buckling, which typically increases the load-bearing capacity of the skeleton 4 times.

The strong material can be cast out in a duct or a groove made in the light material, or it can be established in advance for example as pearl-chain reinforcement.



Compression and tension pearl-chains in a beam

0.2 Pearl-chain reinforcement

Pearl-chain reinforcement is a new invention made during the development of the super-light concrete concept. It reduces the price of optimized structures considerably and makes the building processes more efficient. By means of pearl-chain reinforcement it becomes affordable to provide structures with shapes, which have previously been unthinkable. This allows more resource-economical design, because it removes practical hindrances for application of compression zones with optimal curved shapes.

Pearl-chain reinforcement is a curved compression zone like a spine of a skeleton designed as a chain of prefabricated segments of a strong material assembled by one or more prestressing wires. Casting the compression zone into a light material, the compressive strength of the zone may be used almost fully, because the light material hinders buckling of the zone. This is comparable to the way a spine of a skeleton interacts and is kept in place by the surrounding soft parts of a body.

0.2.1 Compression zones

Prestressing is used for assembly and for stabilizing the chain during erection and casting of the adjacent light material.

0.2.2 Tension zones

If pearl-chain reinforcement is prestressed with a large compression force, the chain can take tensile forces as unloaded compression.

This application makes it possible to make prestressed light-weight concrete, which so far has been almost impossible, because creep of the light-weight concrete would unload the prestressing, and because the prestressing wires may rust if they are not protected by a more dense structure like a pearl-chain.

Prestressed half cylindrical shell at the Royal Theatre in Copenhagen.
Architectural design H. Koppel.
Structural design and photo K. Hertz

1 Material savings of 50 %
Light material such as light aggregate concrete of density 600 kg/m3 or aerated concrete contains mostly air and a few quantities of cheap clay and cement. Therefore, considerable material savings are a consequence of the replacement of strong and heavy materials with light ones for a major part of the structure.

4 Energy and CO2 savings of 50 %
Using the new technology material and energy consumption can be more than halved and consequently CO2 emissions from production, transport, and erection can also be halved, if this is kept in focus choosing the materials.

2 Architectural expressions never seen before
By means of the pearl-chain reinforcement very advanced 3-dimensional curves can be created. Many curved design projects have from time to time been abandoned for economical reasons. Curved moulds, extensive scaffolds, and labour for production have been too expensive. Super-light structures with pearl-chain reinforcement turn these conditions upside down, because it now becomes affordable to make a curved design. Since arches and curved structures usually gives optimized supports for loads, this leads to a situation, where the cheapest and most resource saving design is curved. Therefore, in the future, it must be foreseen that architecture may change as a consequence of the new technology from rectangular shapes to more organic curved expressions.

*Super-light bridge proposal
(Student project
DTU Course 11050
Iwona Budny,
Robert Cybulski,
Agnezka Kotas,
Jan Winkler
2009)*

4 Half price or less

By means of super-light structures, engineers can place compressive forces in optimal paths and the strong material is used to the fullest extent. The remaining part of the structure is filled with a cheap light material. This is the reason why super-light structures can be made much cheaper than traditional structures, where the strong and relatively expensive materials are not confined to a minimum.
If the overall design is made so that tensile forces can be avoided, price reductions of a factor 10 may often be within range.
A number of design cases have been made to document these statements.

Price Example
Beam 30 m long 1.5 m high load 27 kN/m (2.7 ton per meter)

				Price Ratio
Super-light optimal arch	473 dkr/m	≈	63 €/m	1.0
Super-light simple beam	3,504 dkr/m	≈	467 €/m	7.4
Prestressed concrete T beam	3,990 dkr/m	≈	532 €/m	8.4
Welded steel beam	22,165 dkr/m	≈	2,955 €/m	46.9

Scaffolding at the Ordrupgaard museum and a pearl-chain proposal for the same
(Student project DTU course 11050 Trine Bay, Casper Gullach F2009)

5 No Scaffolding and Cheaper moulds

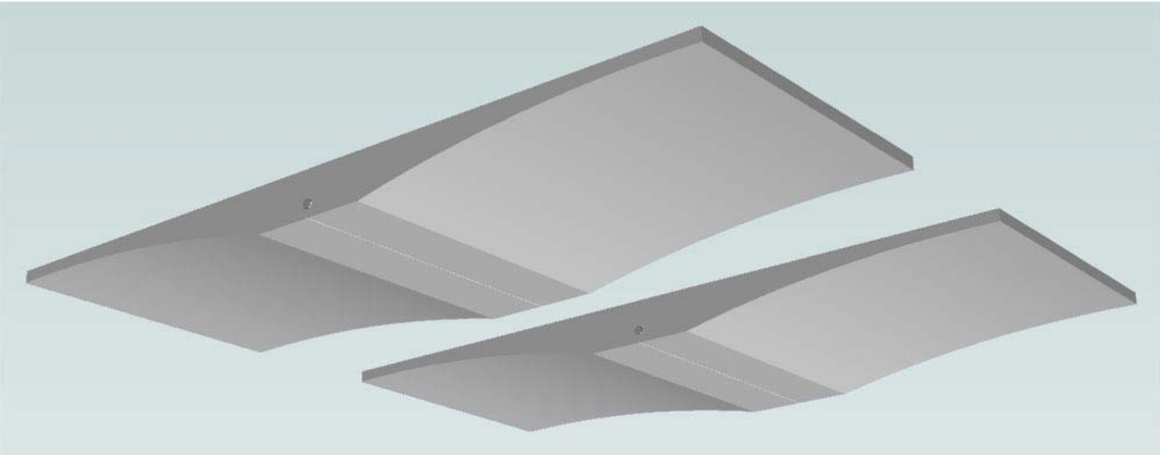
A pearl-chain can be erected without the need for provisional support.
It may also carry moulds for the light material, so that scaffolding can be completely avoided.
The weight of the light weight concrete can be 4 times less than that of ordinary concrete and the pressure on the moulds is 4 times less. Therefore, the moulds can be made of lighter and cheaper materials like for example textiles, which may contribute to a further lowering of the price, energy consumption, and CO_2 emission from the building process. Low weight of the moulds makes it easier for the pearl-chain reinforcement to support them. The many new materials, which can be applied due to the low mould pressure, give architects new possibilities for detailing surface textures and shapes of the structures.

6 Improved durability

Light aggregate concrete does not have the same problems with cracks and frost damages etc. as more dense concrete. Modern investigations and more than 2000 years experiences with a large number of walls, floors, arches, vaults, cupolas, water basins, quays, bridges, and tunnels from Aswan to Scotland document that the material is extremely durable for the weather, water, mechanical impact, earthquake, and fire.

7 Extreme thermal insulation

The new constructions are insulating like wood without problems of rot and fire, and wood is therefore not anymore needed in resource economic buildings.
Light-aggregate concrete with a density of only 600 kg/m3 is cast wet at DTU, and foam concrete is available of the same density, strength and stiffness for structures.
Insulation can be further improved by embedding mineral wool or ultra-light blocks of aerated concrete of densities 100-150 kg/m3. However, foam concrete is also available from 2-400 kg/m3 with very low conductivities as a "floating" insulation material..



Super-light deck elements with pearl-chain arches and pearl-chain cross reinforcement instead of transverse beams Design K.Hertz

8 Better indoor-climate
Application of light aggregate- or aerated concrete in super-light structures introduces a moisture buffer. This absorbs moisture when the air is humid and releases moisture when it is dry leading to an improved in-door climate compared to what you experience in traditional concrete buildings.

9 User friendly operation and maintenance
Walls and ceilings of light-weight concrete, as you will find in super-light buildings, are much easier to drill holes and drive nails in than in traditional concrete buildings. Grooves can easily be cut and covered again, and electric wires, pipes, and ducts can be inserted and made invisible with a minimum of effort. This offers good possibilities for changes, repair and maintenance.

10 Increased safety for fire, earthquake, and explosions
Most indoor structures, tunnels, and off-shore structures should be designed for fire, which usually means that steel structures are protected by insulating plaster, mineral wool or intumescing paint, and traditional concrete structures are over-sized or protected by mineral wool. Especially if a high-strength concrete is applied, it has to be protected for explosive spalling caused by high pressure of steam in the dense material4-7.
Light-weight concrete of a super-light structure can be made very fire resistant and is capable of protecting the strong skeleton. If the skeleton is made of high-strength concrete, it is sufficient to apply 60 mm light-aggregate concrete protection of density 600 kg/m3 in order to protect it from most fires.
Light-weight concrete is capable of absorbing energy from mechanical impact and deformations. This is the reason why the materials have proved to be beneficial for crash barriers. Super-light structures are therefore capable of damping the effect of impact and shakings from explosions and earthquakes increasing the safety for people in buildings made from it.

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